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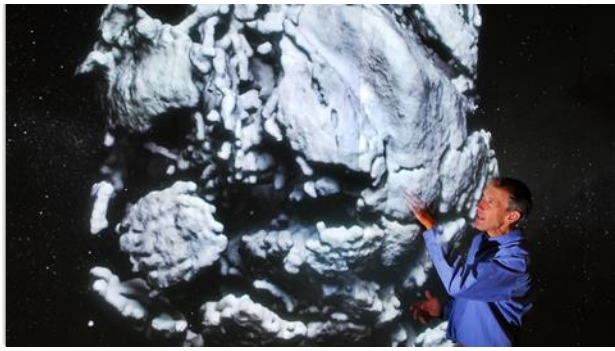

SIRFN Advanced DER Research and System Validation Platform

Tools for the Smarter Grid

A BNL / ISGAN Workshop on Modeling, Simulation and More

Brookhaven National Laboratory, Upton, NY – April 14-15, 2016

Jay Johnson

Photovoltaic and Distributed Systems Integration, Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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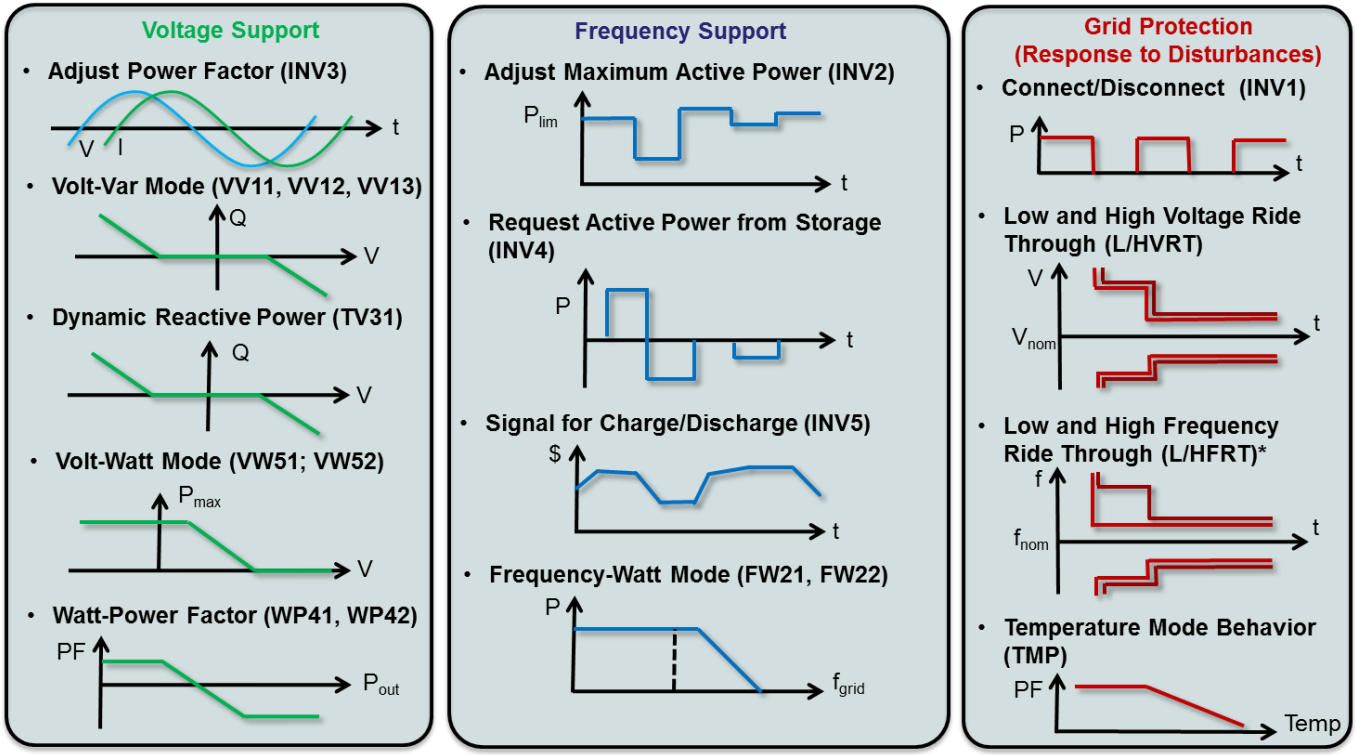
Background

- Total installed capacity of renewables is growing fast in the US
  - The distributed and variable nature of these resources cause a range of challenges for grid operators
- Distributed Energy Resources (DERs) have the ability to help by:
  - **Supporting voltage and frequency** by modulating active and reactive power output
  - **Tolerating grid disturbances**
  - Interacting with grid operations via **communications**
- These capabilities are enabled through **multiple advanced DER functions**
  - They are being **codified by a number of standards development organizations** (SDOs)
  - It's necessary to **verify their functionality prior to wide-spread deployment**
  - Testing for US products will be conducted according to **UL 1741 SA**
- Smart inverters have dozens of operating modes and 100s of parameters
  - Verifying the operation of all the combinations of functions and parameters would be **cost and time prohibitive without test automation**.
  - Sandia and SunSpec Alliance are creating a tool called the **System Validation Platform (SVP)** to perform this automation.

Advanced Interoperability Functions

- New 'smart' inverters will include multiple advanced functions
  - Autonomous: Inverter response to local voltage and frequency conditions
  - Commanded: Remote control (e.g., on/off, set power factor)
- Utilities will modify distributed energy resource (DER) behavior using communications.



Similar functions are in California Electric Rule 21, UL 1741 SA, and IEEE 1547 full revision.

Many countries in Europe have defined similar functions.

Advanced functions as defined in IEC TR 61850-90-7, *with the exception of FRT.

Development of Rule 21 Certification Procedures

- UL 1741 Supplement A (SA) – "Grid Support Utility Interface Inverters and Converters" has been drafted!
  - Designed based on the CA Rule 21 Phase 1 functions, but will evolve with IEEE 1547 revision.
  - UL expects STP final approval in the June timeframe.
  - Tests include:
    - Anti-islanding Protection
    - Low and High Voltage Ride-Through
    - Low and High Frequency Ride-Through
    - Normal Ramp Rate
    - Soft-Start Ramp Rate
    - Specified Power Factor
    - Volt-Var Mode
    - Frequency-Watt (optional)
    - Volt-Watt (optional)

The Future of Certification Testing

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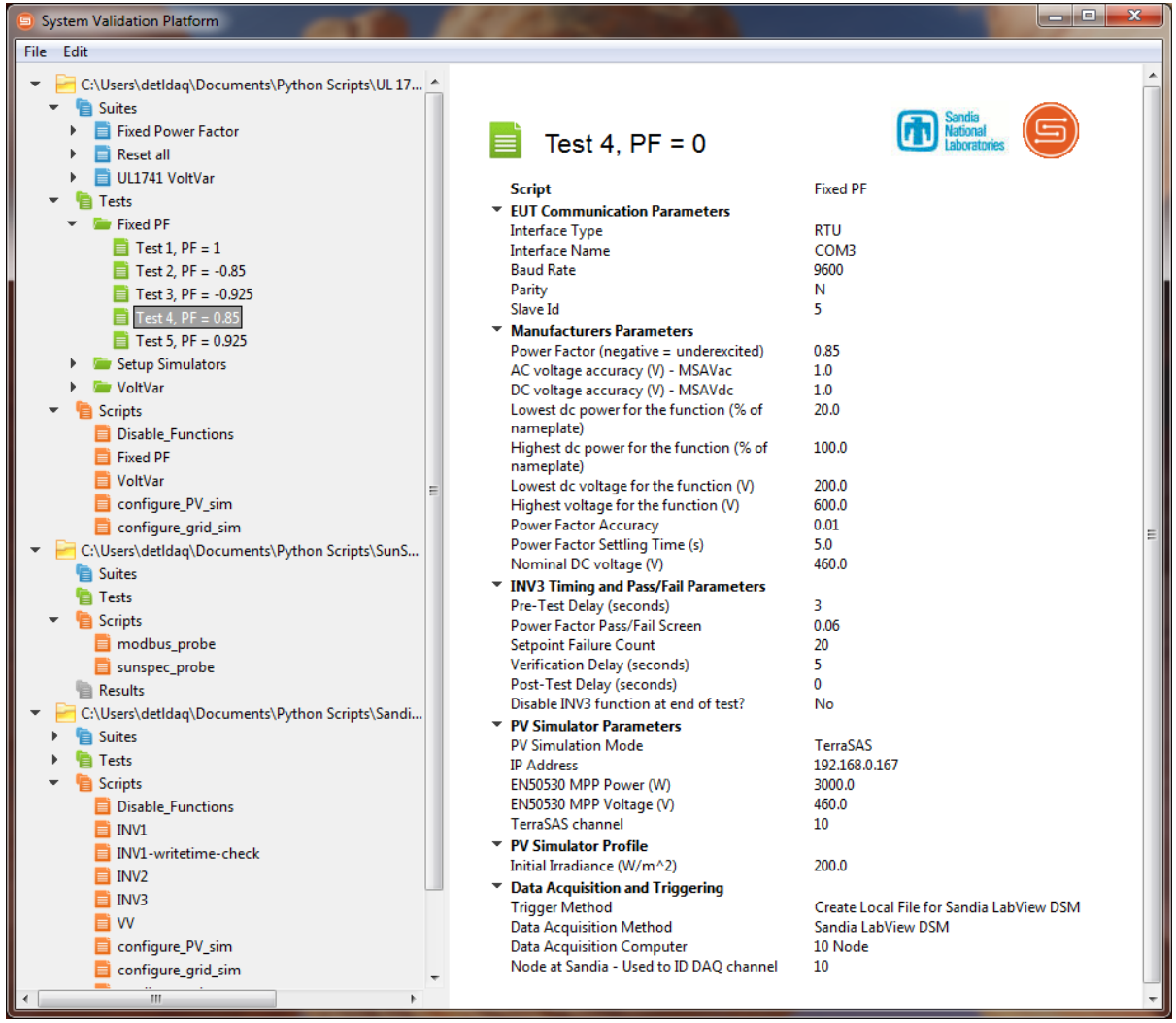
- Have you been struggling to complete your grid-support function testing on time?
- Is your company behind schedule because of the number of permutations in UL 1741 SA?
- Have you grown tired of adjusting AC and DC simulator settings?
- Have you found yourself repeating tests after messing up some of the experimments?
- Are you looking for a fast, accurate testing tool?

- Then the System Validation Platform is for you!

SunSpec/Sandia System Validation Platform

- System Validation Platform (SVP) is an automated certification interoperability platform
  - Fully scriptable
  - Interacts with DAQs, PV and grid simulators, and DER.

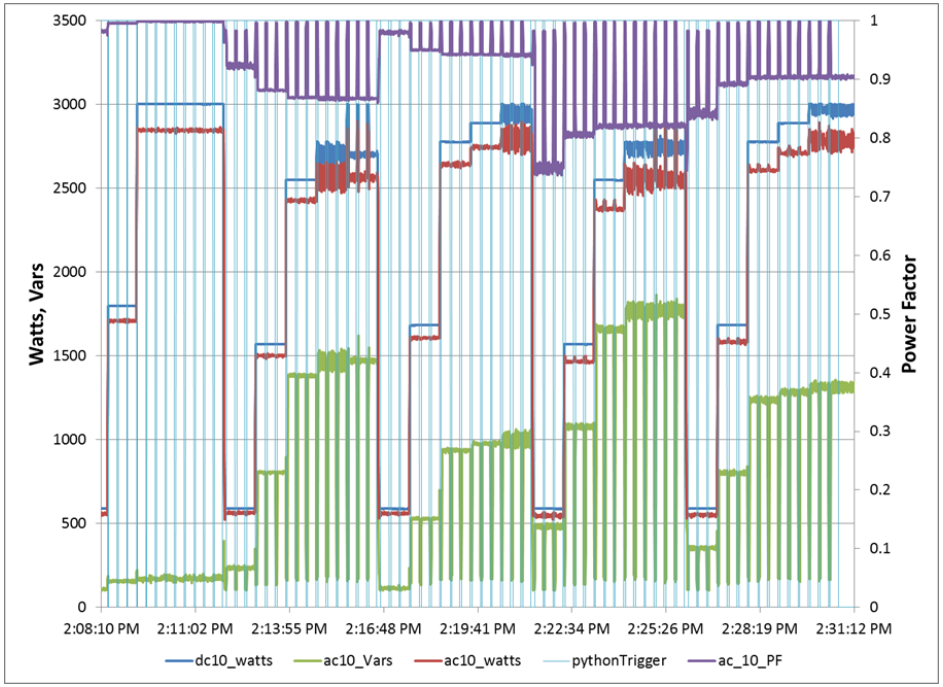


http://sunspec.org/sunspec-svp/
http://sunspec.org/download-svp/
https://github.com/sunspec/svp_directories

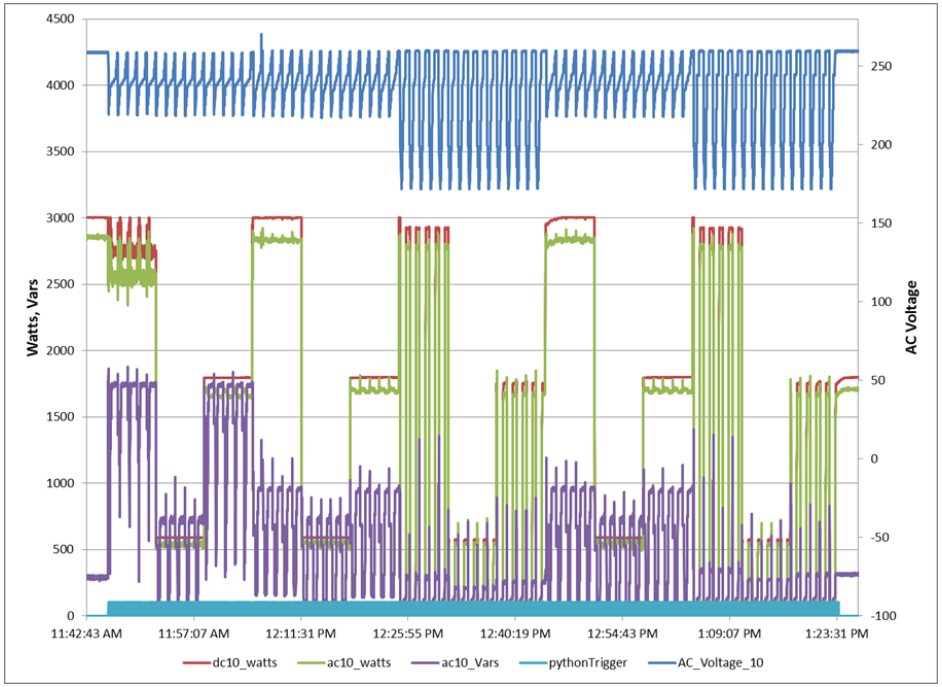
Power of Testing Automation

- UL 1741 SA test permutations are large due to the number of settings in each advanced DER function:
  - 75 measurements for fixed power factor - takes about 25 minutes with the SVP
  - 375 measurements for volt/var - takes about 90 minutes with the SVP

Proposed UL 1741 SA fixed power factor tests.



Proposed UL 1741 SA volt-var tests.



More in: J. Johnson, B. Fox, “Automating the Sandia Advanced Interoperability Test Protocols,” 40th IEEE PVSC, Denver, CO, 8-13 June, 2014.

SIRFN Smart Grid Collaboration

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- IEA (International Energy Agency)
  - Clean Energy Ministerial (CEM)
    - International Smart Grid Action Network (ISGAN)
      - **Smart Grid International Research Facility Network (SIRFN)**
        - Smart Grid Distribution Automation
        - Advanced Laboratory Testing Methods
        - Power Systems Testing
        - Test Protocols for Advanced DER Functions

SIRFN - A coordinated network of smart grid research facilities from:

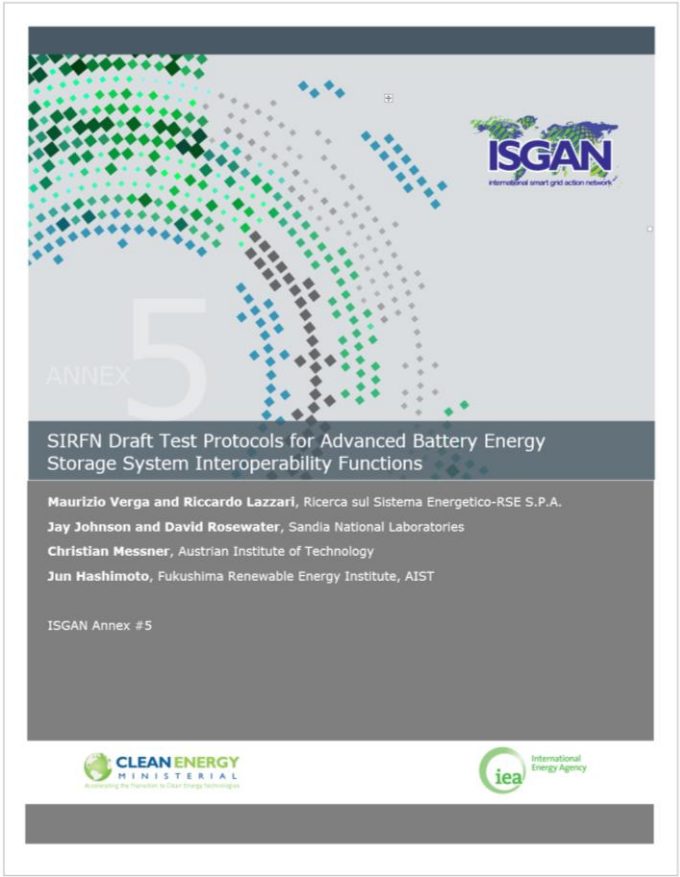
- **Primary goal**: Develop and demonstrate a consensus-based interoperability certification standard for advanced Distributed Energy Resources (DERs).
  - Design and compare advanced interoperability test-beds.
  - Perform round-robin testing of advanced DER.
  - Compare test results, communications methods, and automation procedures.
  - Gradually improve draft test procedures for advanced DER with the goal of becoming an internationally-accepted standard.

Some Experimental Results: J. Johnson, R. Bründlinger, C. Urrego, R. Alonso, "Collaborative Development Of Automated Advanced Interoperability Certification Test Protocols For PV Smart Grid Integration," EU PVSEC, Amsterdam, Netherlands, 22-26 Sept, 2014.

Protocol Development Process

1. Review of appropriate grid codes, technical rules, standards, and ESS functions
2. Consolidation of function requirements into draft protocol language
3. Execution of draft protocol to ESS with equipment units at SIRFN laboratories
4. Updating draft protocols to improve usability and to generate better results

Protocols will be published soon for active power, reactive power, fixed power factor, volt-var, and frequency-watt.



Execution of draft protocol to ESS: SIRFN Testing Laboratories

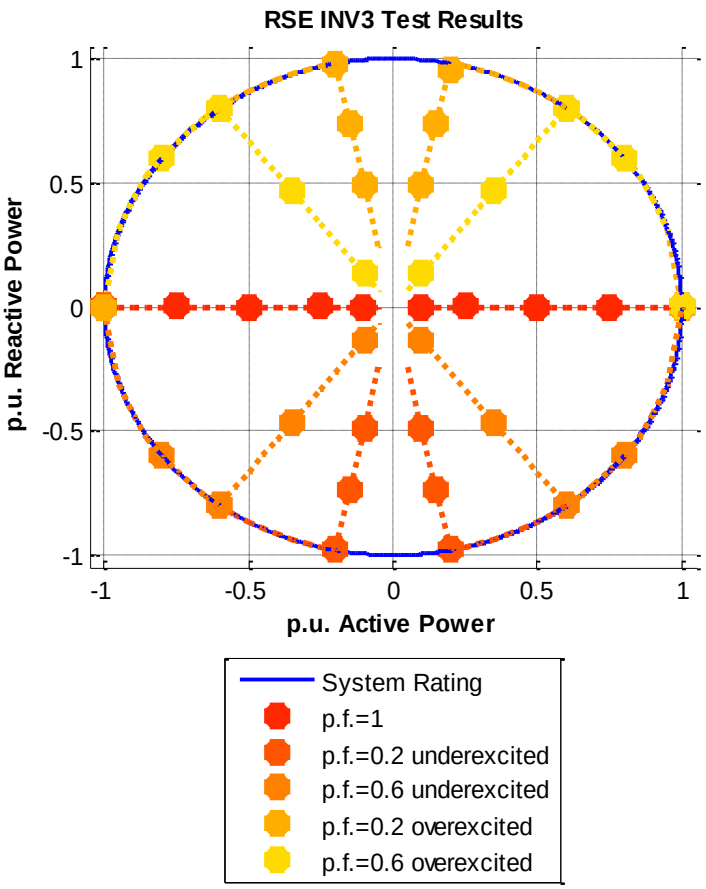
Team members at AIT Smart Electricity Systems and Technologies (SmartEST) PV Inverter Test Laboratory

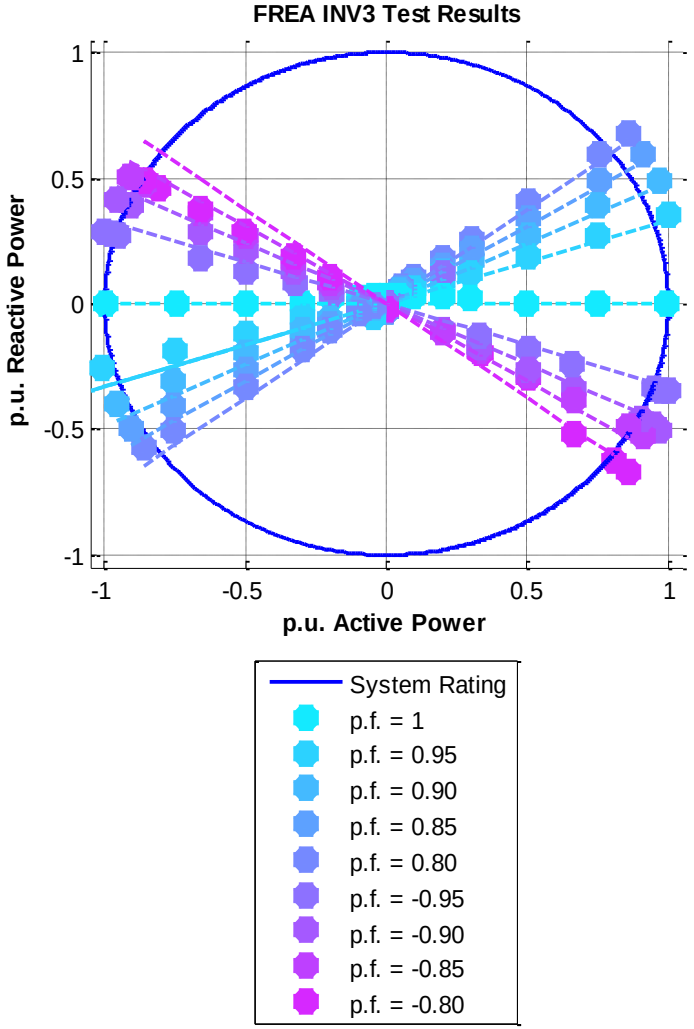
Team Members at RSE Distributed Energy Resource (DER) Test Facility

Team members at FREA Smart DER Research Facility

Team Members at Sandia's Distributed Energy Technologies Lab (DETL)

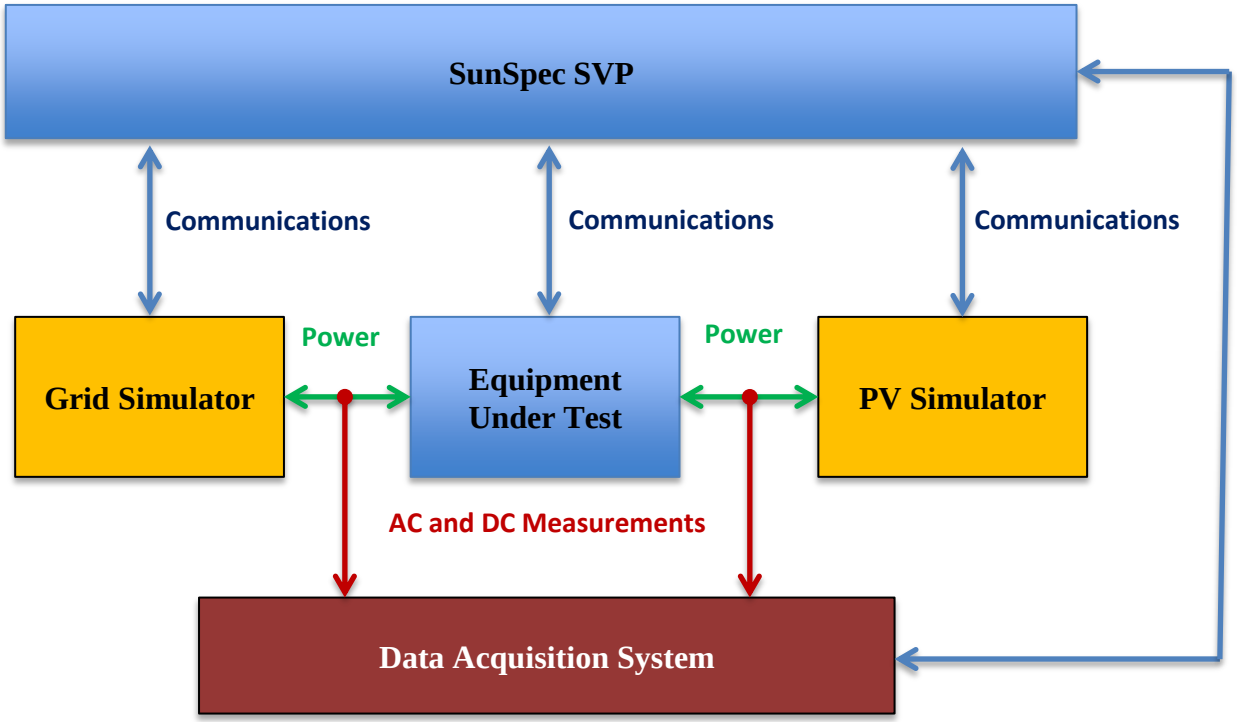
Review Data and Refine Protocols: Commanded Power Factor





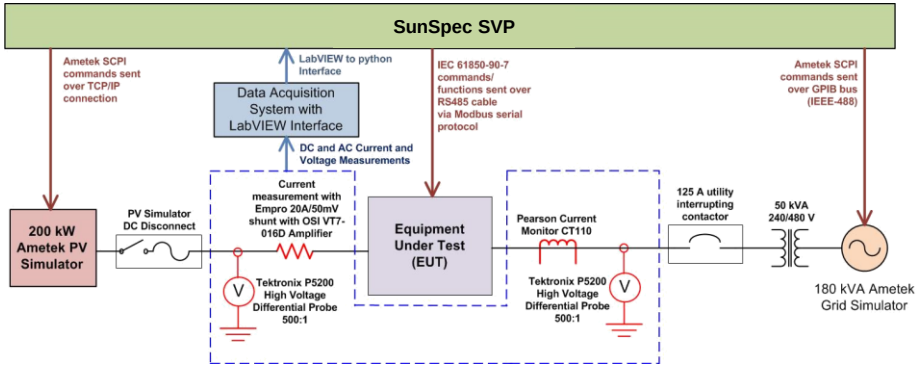
SVP Architecture

- Abstraction layers in python allow the same scripts to be executed for any PV simulator, grid simulator, DAQ, and EUT with the associated communication driver.



More in: J. Johnson, B. Fox, "Automating the Sandia Advanced Interoperability Test Protocols," 40th IEEE PVSC, Denver, CO, 8-13 June, 2014.

SVP Deployment at SIRFN Labs and other Facilities



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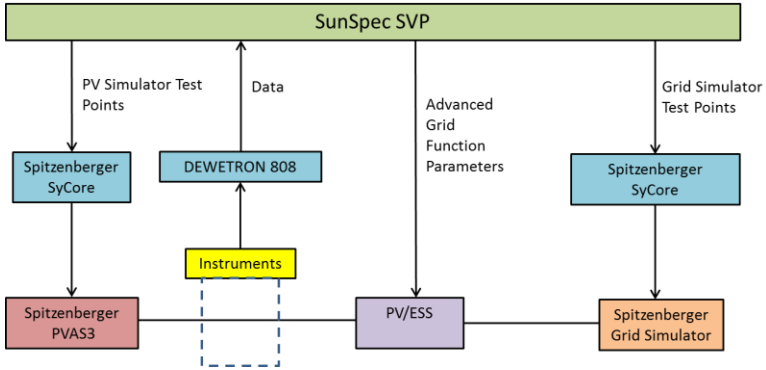
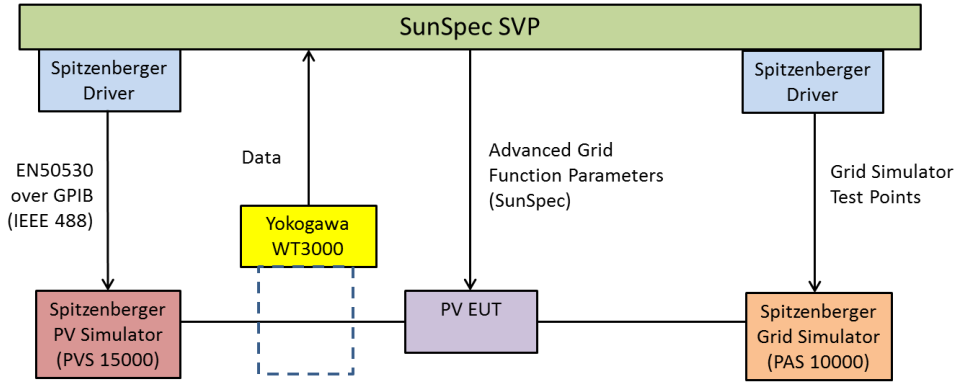
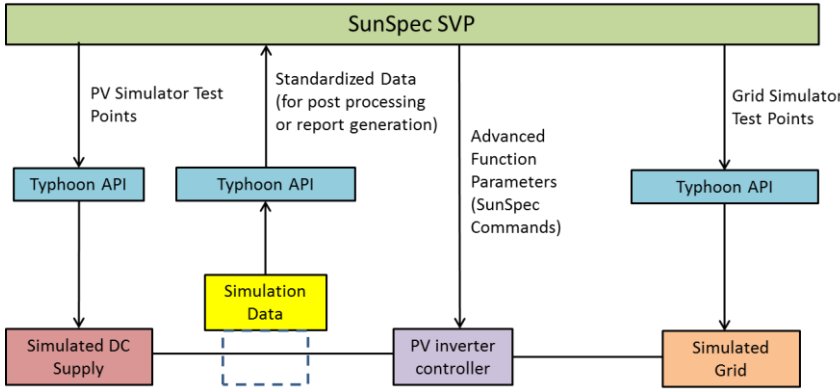


Austrian Institute of Technology



Ricerca sul Sistema Energetico (Italy)



Sandia National Labs and AIT
(Control Hardware-in-the-Loop Configuration)

Other labs using the SVP:

- Fukushima Renewable Energy Institute, AIST
- Underwriters Laboratories
- University of California - San Diego

SIRFN Next Steps

1. **Complete/refine test scripts** and parameters for each of the test protocols, including UL 1741 SA

2. **Execute SVP test scripts** at each of the laboratories
   a. **Compare results** for accuracy of the SVP operations, equipment variations, DAQ accuracies (especially w.r.t. pass/fail criteria), etc.
   b. **Improve SVP scripts** with error checking, faster execution, etc. through crowd sourcing and the github repository

3. Provide **working directories to NRTLs** and other testing facilities.

4. **Suggest improvements to the codes/standards** based on results
   a. Many of the protocols have not been vetted with experimental tests by the SDO - clarifications and corrections are likely

Conclusions

- Advanced **DER functions help support the electricity grid**.
- In the US, **UL 1741 SA is nearly finalized** and there will be many manufacturers rushing to complete certification tests.
  - Need for automation to complete tests with minimal cost and time requirements.
  - SunSpec SVP offers one solution.

- **Sandia, SIRFN, and SunSpec** are also **improving certification protocols and test capabilities** by:
  - Building test-beds for advanced inverter testing (electrical performance and interoperability).
  - Comparing advanced DER test results and improving draft certification protocols.
  - Recommending improvements to national and international codes and standards.

- **Standardized test methods for** verifying **interoperability** are **critical** also.
  - **Communications certification not defined**; cybersecurity a big concern.

Questions?

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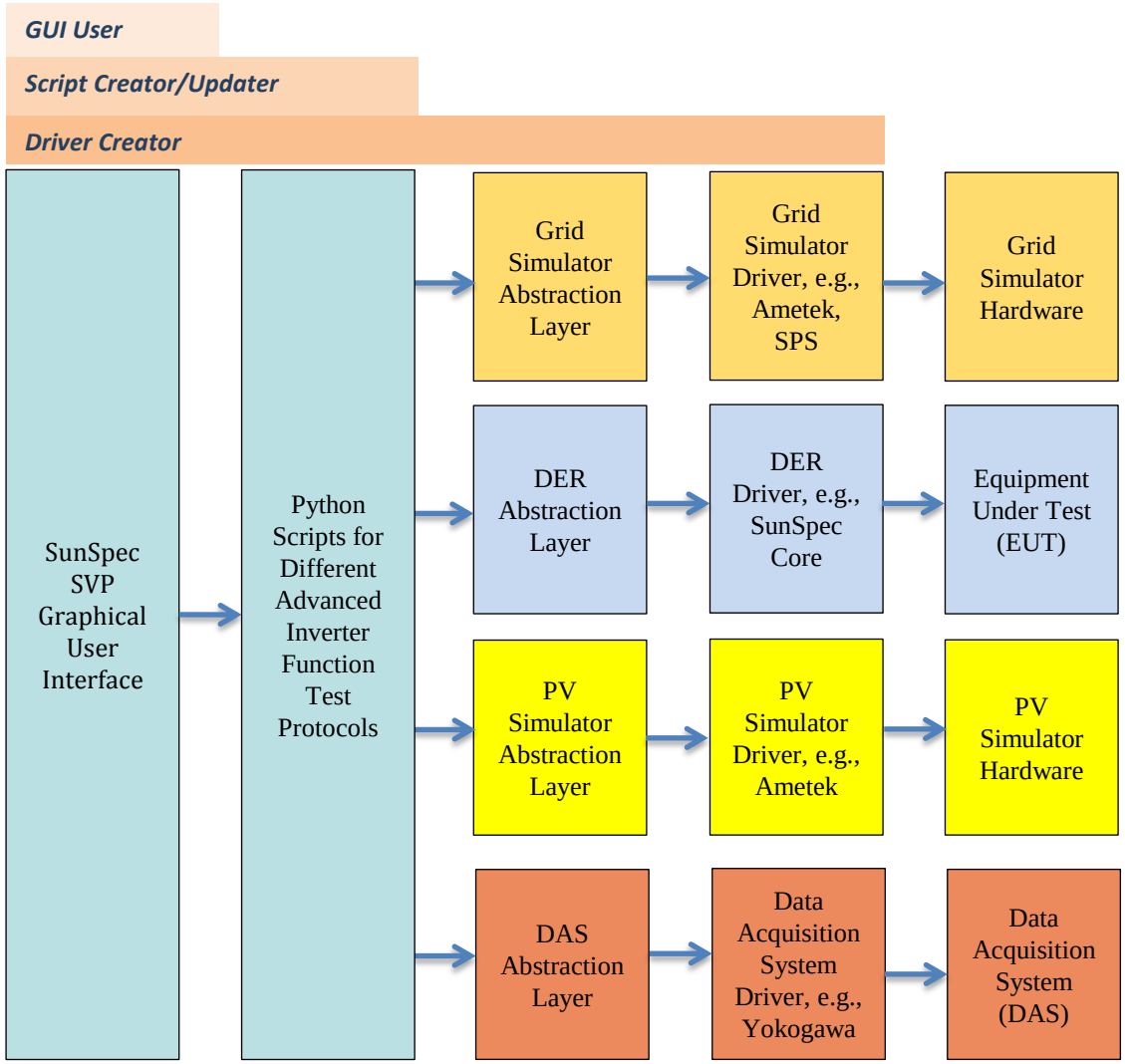
Status of SVP Python Scripts

Sandia National Laboratories

- Sandia Test Protocols
  (for IEC 61850-90-7 functions)
  - FW
  - INV1 (connect/disconnect)
  - INV2 (active power curtailment)
  - INV3 (fixed power factor)
  - VV
  - FRT (*nearly complete*)
  - VRT (*nearly complete*)
- SIRFN ESS Protocols
  - FW (draft)
  - VV (draft)
- UL 1741 SA
  - Normal Ramp Rate
  - Soft-Start Ramp Rate
  - Specified Power Factor
  - Volt/Var Mode
- SunSpec Utilities
  - Disable functions
  - Configure PV simulator
  - Configure AC (Grid) simulator
  - Record EUT-reported data

Open source working directories: https://github.com/sunspec/svp_directories

SVP User Domains



More in: SunSpec System Validation Platform, SunSpec Alliance Users Guide, Version 1.0.

Review Data and Refine Protocols: Commanded Active Power